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Short and Project Papers

3D reconstruction of archaeological sites using photogrammetry

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Abstract

The 3D reconstruction of an archaeological site is a difficult task, taking into account the available documentation. Our team, supported by the TGE Adonis, is specialized in 3D reconstruction and conservation of 3D data. We already use numerous sources, like excavation documentation, ancient texts, any kind of representation, land surveys, in-situ pictures, laser or time of flight scannography, and experiments of archaeologists, anthropologists and architects. Since the 80's, each model we produce are scientifically checked by specialists, and regularly updated to follow new knowledges and investigations.

In this paper, we present the use of photogrammetry to reconstruct a 3D model of an archaeological site, as a new source of data, less expensive and more accessible than scanners. We present concrete cases: a chapel (12 century p.C., Moissac, France), catacombs of St Pierre et Marcellin (250 p.C., Rome, Italy) and a roman coin (5 a.C., Loron, Croatia). The question of scale and texture mapping is explored through the software like photomodeler and PMVS.

Finaly, we discuss the accuracy of photogrammetry in comparison to scanners, the accessibility of this technique to archaeologists, and the interest for fragile artefacts in museums.

1. Introduction

The PFT3D (PlateForme Technologique 3D) is a team of Ausonius, a research unit from CNRS and Bordeaux 3 University. We experienced from the 80's new technologies for archaeological 3D reconstructions, starting from PDMS, a software for making offshore oil platform or nuclear power plant, to photogrammetry, through modelisation and laser scanner. Today, we use Autodesk 3DSMax for modelisation, laser scanner, time of flight scanner, and photogrammetry for the acquisition. Each project is associated with a research group composed of specialists where the 3D model is a common way of communication between them. They bring knowledge and sources like excavation documentation, ancient texts, any kind of representation, land surveys, and in-situ pictures. All input and produced data are saved in a national 3D conservatory for archaeological projects: Archeogrid. This storage is supported by the TGE Adonis.

Photogrammetry begins to be very popular and it is useless to prove its interests. In this paper, we present how and why we choose this technique to help in reconstructing 3D models of achaeological sites or objects. Beyond simple tests, we present feed back about the use of different softwares, and troubles on scaling and mapping texture. The first location is a chapel from the 12 century p.C. in Moissac (France). The inside and particulary the painted vault are studied. The second are the catacombs of Saint Pierre et Marcellin in Rome (250 p.C.). The interest is the uncommon shape of each room, the exiguity, and the vulnerability of the ground full of skeletons. The last example is an ancient roman coin from 5 a.C. The study of rare object using a virtual model is much difficult when the object is small. In fact, the 3D model, geometry and textures, must be very accurate to be correctly examined.

Those projects are processed using PMVS [FP09] and for some of them, photomodeler [Eos10]. Each software has its advantages and inconvenience, but both require a lot of computation power.

Finaly, we discuss the accuracy of photogrammetry in comparison to laser or time of flight scanners. The vantage of photogrammetry is not obvious for all cases.

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2. The complete task of a 3D reconstruction

The reconstruction needs several sources, and specialists to read and interprete them. The first step is to build a team in wich each specialist can supply help and documentation. Here, photogrammetry already raises the problem of who is the specialist. A Photograph knows how to take a picture, an archaeologist knows what is important to reconstruct, and a computer scientist specialised in photogrammetry is the only one who really knows how pictures must be taken for a 3D reconstruction. Ideally, the archaeologist shows to the computer scientist what is important, and the computer scientists explains to the photograph how to rotate around the object, how many picture he needs, and what are the best settings for the camera.

The first model is established from a set of in-situ statements including pictures for photogrammetry. The model can evolve with the emergence of new technologies, or new photogrammetry software. So, it is crucial to save original pictures to allow a new reconstruction of a model.

After, other sources are incorporated into the virtual model to complete the representation of in-situ vestiges, and optionnaly, the model is embeded by hypothesis of reconstructions.

3. Concrete cases

3.1. Chapel, Moissac, France (12 century p.C.)

- 58 pictures: figure 1
- 1 000 000 points
- computation time: PMVS 16 hours at half resolution: figures 2 and 3
- interest: architecture and paintings
- choice of photogrammetry: the texture mapping is as important as geometry, and techniques of mapping pictures on 3D point cloud from laser scanner are not enough efficient and sterling.
- device: nikon D700 12 Mpx, optic 24-70 F/2.8

Figure 1: *Moissac chapel.*

3.2. Catacombs, Rome, Italy (250 p.C.)

- 17 pictures each room: figure 4

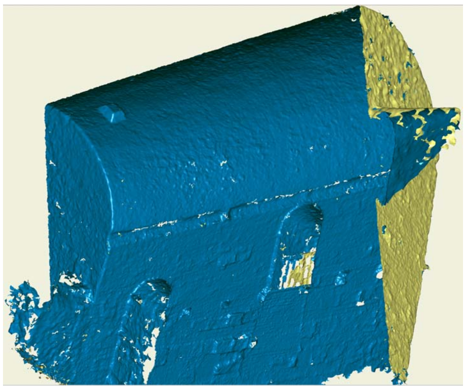

Figure 2: *Moissac chapel: part of the mesh without texture.*

Figure 3: *Moissac chapel: part of the textured mesh.*

- 500 000 points each room
- computation time: PMVS 5 hours each room: figures 5 and 6
- interest: understand how humans were stacked and buried
- choice of photogrammetry: exiguity and access of each room and bones lying on the ground allows only introduction of small devices.
- device: nikon D700 12 Mpx, optic 12-24 sigma

Figure 4: *St Pierre et Marcellin catacombs.*

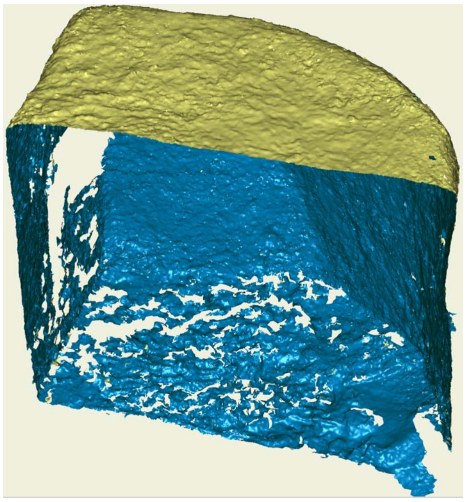

Figure 5: *Catacombs: part of the mesh without texture.*

Figure 6: *Catacombs: part of the textured mesh.*

3.3. A roman coin, (5 a.C.)

- 5 pictures: figure 7
- 400 000 points
- computation time: 2 hours: figures 8 and 9
- interest: manipulate a virtual copy of a fragile artefact for studies.
- choice of photogrammetry: precision of texture mapping, and tests of macro optic.
- device: nikon D700 12 Mpx, optic micro nikkor 60mm

Figure 7: *Roman coin.*

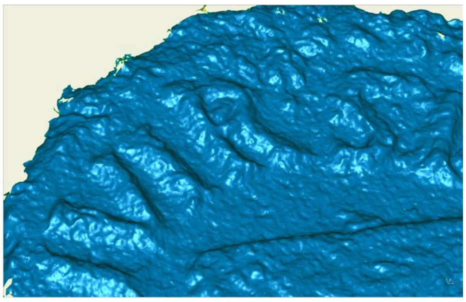

Figure 8: *Roman coin: part of the mesh without texture.*

4. Software used: Photomodeler and PMVS

4.1. Specifications

Photomodeler runs on windows opertaing system. The first step is to generate a calibration file of the camera by taking a picture of special test card. Photomodeler uses couples of pictures with a small displacement of the camera to compute the point cloud. 2 types of reconstruction are possible:

Figure 9: *Roman coin: part of the textured mesh with edge enhancement.*

- manual: the operator have to pick reference points on each couple of pictures, and photomodeler will check when the reconstruction is possible;
- automatic: the operator have to place tests cards around the objet or on the site. Photomodeler reconize tests cards, computes the camera position and scale the model to reality;

Photomodeler is also able to compute a texture for a classical mapping on a mesh.
PMVS [FP10] is supposed to run on windows operating system, but batch script is provided only for linux, or eventually, for cygwin. For each picture, it uses a text file containing a matrix for 3D computations. Thoses matrices can be computed by bundler [Sna10,NS06,NS07] and it seems to be the only way. Bundler uses sift [Low04] algorithm that runs only on a 32 bits system. So, matrices computations are made on linux 32 bits, and PMVS computations on a linux 64 bits. PMVS don't use tests cards, so the final scaling is up to the operator. Thats why we recommend to make some measurements on the site or the object to get the 3D model correctly scaled. Pictures must be taken from differents point of view without any kind of constraint.

4.2. Troubles

The manual option for photomodeler is time consuming, but gives good results, unlike automatic option is faster but tests cards are very binding. Texture generation gives hazardous results with bad projections and long computation time.
For PMVS, the sift program included in bundler have limitations and throws exceptions on too heavy pictures. We were obliged to resize picture to 75% or 50%.
Texturing is color per vertex. The definition of pictures is lost because there are less vertices than texels.
The use of 2 different operating systems for PMVS is binding but necessary because it uses a very big memory amount. PMVS have an option to reduce pictures that barely reduce computation time and memory needs.

5. Discussion

5.1. Comparison to laser or time of flight scanners

On small objects, with macro optics, the resolution is greater and noise is smaller with photogrammetry than with laser scanner. The precision is difficult to evaluate because laser scanners are references in those cases, but we measure a meaning of differences between two meshes inferior to 0.1 mm.
Acquisition is more rapid taking into account the same setup time. But the software used does not allow a real time 3D visualization of acquired parts unlike laser scanner. Some new scanners based on photogrammetry and pattern projection are able to reconstruct 3D meshes in real time, but they use special devices and not classical cameras.

5.2. Texture mapping

The photogrammetry uses pictures to generate a mesh, that's why each texture is necessarily well located. That is also the case for picture taken by some classical scanner, but those texture are always of poor quality and replaced by camera-taken pictures, mapped by some obscur algorithms.
Actually, none of photomodeler or PMVS gives a correct texture extracted from pictures, and mapped on a mesh, but it is obvious that it will come soon.

5.3. Accessibility and cost

The acquisition protocol is software dependent. Photomodeler works with couples of picture, while PMVS works with single but numerous pictures. Conditions of lightning and background, and the quality of the optic and the picture are important to obtain the best results. Nevertheless, pictures are taken from reflex camera, and archaeologists are able to take pictures for photogrammetry purposes themselves.
The cost is determined by the camera, and eventually a software. In fact, despite its weaknesses for textures and the difficulty to make it runs, PMVS is free and gives very good results.

5.4. Custom developements

Numerous algorithms are free and it is up to any one to contribute to the improvement of existing softwares. Thanks to the support of TGE Adonis, the PFT3D has access to a computing cluster, and plan to develop, in collaboration with the LaBRI (Laboratoire Bordelais de Recherche en Informatique), a distributed software for photogrammetry computation. Once developed, the software will be free and available on Internet for the archaeological community.

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